The safety assessments of reaction vessels used for the space exposure experiments in order to synthesize nucleotide by UV irradiation

*白水 まどか[1]、中川 和道[2]、別所 義隆[3]、三田 肇[1]
*Madoka Shiromizu[1], Kazumichi Nakagawa[2], Yoshitaka Bessho[3], Hajime Mita[1]

1. 福岡工業大学、2. 大阪大学、3. 台湾中央研究院・生物科學研究所
1. Fukuoka Institute of Technology, 2. Osaka University, 3. Academia Sinica, Institute of Biological Chemistry

1. Introduction

Nucleotides are constituents of DNA and RNA, the process of nucleotide synthesis in the primitive Earth is one of the most important processes in the origin of life.
In the previous studies, nucleobases and sugars have been found in the carbonaceous chondrites and the simulated primitive Earth experiments. Thereby, source materials of nucleotides would be existed in the primitive ocean. And, molecular oxygen and ozone didn’t exist in the atmosphere of the primitive Earth. This suggests that the short wavelength (≦280 nm) UV lights, which is interrupted at the surface of the present Earth, reached to the surface and worked as an important energy source for the chemical reactions at that time. Therefore, we proposed a hypothesis that nucleotides would be synthesized by the UV irradiation in the primitive ocean.
In order to verify this hypothesis, nucleotide synthesis experiments using the Japanese exposure facility on the International Space Station (ISS) as a similar UV environment to the primitive Earth are proposed in the part of the “TANPOPO 4” mission. “TANPOPO” is series name of the astrobiology experiments in Japan using the ISS. In the previous "TANPOPO" mission, films or powdered organic compounds were exposed to the space environment. But this nucleotide synthesis would be performed under aqueous solution. Then, new apparatus those are able to used in the space exposure experiment should be required. The exposure facility on the ISS is in environment of ultra-high vacuum and rapid temperature changes. The reaction vessel containing the aqueous solution should be sealed completely and the seal should withstand the drastic temperature changes in ultrahigh vacuum. Therefore, we developed vessels that can expose the aqueous solution to UV rays by improving the cells used in the TANPOPO experiments.
In this paper, nucleotide synthesis experiments by UV irradiation and the preliminary safety assessments of new developed reaction vessels those are based on the previous TANPOPO mission were performed.

2. Experimental method

Equimolar solution of nucleobases and ribose-5-phosphate (R5P) were mixed and irradiated with UV light (172 nm) for 4 days. This irradiation is equivalent to approximately one year of irradiation on the ISS orbit. After irradiation, irradiated solutions were analyzed by high-resolution LC/MS in order to confirm the synthesized nucleotides.
The reaction vessel was placed in ultra-high vacuum environment where the temperature changes drastically and left for several months. The changes in degree of vacuum and mass were observed, and it was tested whether the solution leaked from the reaction vessel.

3. Result

Five kind of nucleotides were synthesized by UV irradiation. Adenylic acid was the highest yield and thymidylic acid was not found after irradiation. Furthermore, it was found that the addition of Ni^{2+} ions

increased the yield of adenylic acid. The conformational analysis of the synthesized nucleotide will be performed.
We improved the structure-assessed cells used in the TANPOPO experiments and construced the reaction vessels for UV exposure that can seal the aqueous solution (Figure). Since the surface temperature of the ISS changes from 30 to -40 ℃, the solution freezes and melts repeatedly. A little air was admitted into the reaction vessel to prevent the MgF_2 glass from breaking due to volume expansion when water was frozen. The sealing test under ultra high vacuum and repeatedly temperature change conditions showed that the reaction vessel did not break and did not leak solution. In addition, this reaction vessels withstood the maximum vibration at launch and landing on water in the random vibration test. In the future, we will investigate the strength change of the O-ring inside the reaction vessel by UV irradiation and temperature change.

キーワード：アストロバイオロジー、生命の起源、ヌクレオチド、紫外線照射
Keywords: astrobiology, origin of life, nucleotide, UV irradiation